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Variation in Damage from Growing-Season Frosts Among Open-Pollinated Families of Red Alder

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Abstract

Repeated growing-season frosts during late April and early May 1985 caused extensive damage to red alder (*Alnus rubra* Bong.) seedlings in a newly planted research trial in western Washington. About two-thirds of the seedlings were severely damaged (entire stem damaged or necrotic). Such damage varied by family, from 50 percent of seedlings in the least affected family to nearly 90 percent of seedlings in the most sensitive family. Seedlings planted in plots fertilized with triple superphosphate suffered greater damage than those in unfertilized plots.

Introduction

Red alder (*Alnus rubra* Bong.) exhibits rapid juvenile growth, fixes atmospheric nitrogen in its root nodules, and occurs naturally over a wide range of soil and site conditions. Such traits make it well-suited for use in intensive cultural systems designed to produce energy and/or fiber in short (10- to 15-year) rotations. In recent years, many research and pilot plantations of red alder have been established successfully throughout western Oregon and Washington.

In spring 1985, we established a field experiment to test effects of several cultural practices on productivity of red alder plantations. The experimental plots were planted with container-grown seedlings from 18 open-pollinated families. Buds began to swell in mid-March and most trees leafed out during the next 2 weeks. Several frosts occurred during late April and early May, causing extensive damage to the newly planted alder. By late May, at least 50 percent of the alder seedlings had been severely damaged. Although the damage necessitated replanting the experiment in spring 1986, the loss did provide an opportunity to observe variation in frost damage to newly planted red alder seedlings. This note discusses the temperature patterns that led to the severe frost damage in spring 1985 and examines the variation in damage among red alder families included in our study.

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Study Area and Methods

The site is located 12 km east of Olympia, Washington, on land managed by the Washington State Department of Natural Resources (DNR) as a Douglas-fir seed orchard. Topography is level to very gently rolling, and the soil is a Nisqually sandy loam. The site was prepared by plowing and disking in early January 1985.

The study involved an examination of effects of family, spacing, irrigation, and phosphorus fertilizer on early growth of red alder. The experimental design was a split plot, with spacing, irrigation, and fertilizer treatments applied to whole plots and families randomly assigned to subplots. The experiment was replicated in three blocks. Triple superphosphate was applied in late January at 300 kg P per ha to plots designated for fertilizer treatment.

The seedlings had been grown in Styro-8[1/] containers, using a 50:50 mix of peat and vermiculite, at DNR's Mike Webster Nursery near Olympia. Seeds were sown in mid-May, and seedlings were grown to 10 cm height in greenhouses; in mid-June, they were moved outside to complete their growth and to harden off under partially shaded conditions. Seedlings from 18 open-pollinated families were removed from the Styro blocks and planted in late February 1985 when they were 20 to 30 cm tall. The family identity of each seedling was recorded on plot maps. Characteristics of the parental sites for the 18 families are given in table 1.

Frost damage data were collected in July 1985 on all plots that had been planted at 1- by 1-m spacing. Each plot contained a total of 324 trees (16-20 trees of each of the 18 alder families). Irrigation treatments had not been applied. Thus, two fertilized and two unfertilized plots were examined in each of three blocks. The assessment involved nearly 3,900 trees and included at least 200 observations for each family.

Each seedling was examined for frost damage and scored according to the following categories:

Severe—100 percent of stem damaged or necrotic (may or may not be resprouting from base).
Moderate to Heavy—50 to 99 percent of stem damaged or necrotic.
Light or None—0 to 49 percent of stem damaged or necrotic.

Data were compiled to provide the percentage of trees scored in each category in each family-fertilizer subplot. After transformation to arcsin values, the data were analyzed statistically as a randomized complete block design with fertilizer as the main plot treatment and family as the subplot treatment (table 2). Means were separated by Tukey's test using $P < 0.05$ as the level of significance.

Temperature data were obtained from the official weather station at the Olympia airport, located about 15 km southwest of the site. The data were examined for patterns that might explain the severe damage encountered in spring 1985 and summarized as the number of frosts and minimum temperature (below freezing) by 10-day periods from March 1 through May 31.

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Table 1—Characteristics of parental sites for red alder families planted in the Department of Natural Resources seed orchard

Family		Elevation	Latitude	Approximate distance from saltwater	Temperature[1] Mean January minimum	Mean July maximum
No.	Name	m		km	-Degrees Celsius-	
1	Vancouver Island #1	50	50° 20' N	<5	2.2	17.6
2	Vancouver Island #2	50	50° 20' N	<5	2.2	17.6
3	Capital Forest #1	150	46° 50' N	10	-1.1	25.3
4	McCleary W-10	500	46° 50' N	15	-1.1	25.3
5	McCleary SP-28	100	47° 10' N	20	-0.4	24.6
6	McCleary SP-36	100	47° 10' N	20	-0.4	24.6
7	McCleary RC-42	250	46° 50' N	10	-0.2	25.3
8	McCleary Mc-62	75	47° 00' N	15	-0.4	24.6
9	McCleary Mc-71	75	47° 00' N	15	-0.4	24.6
10	Nisqually Delta 402	50	47° 00' N	<5	1.3	23.5
11	Nisqually Delta 404	50	47° 00' N	<5	1.3	23.5
12	Nisqually Delta 405	50	47° 00' N	<5	1.3	23.5
13	Nisqually Delta 407	50	47° 00' N	<5	1.3	23.5
14	Elbe 420	400	46° 40' N	30	0.9	25.6
15	Forks 9	50	47° 50' N	20	0.5	21.3
16	Forks 15	50	47° 50' N	20	0.5	21.3
17	Johns River J-1	150	46° 50' N	10	1 1	20.9
18	Johns River I-2	150	46° 50' N	10	1.1	20.9

1/ From nearest weather station listed in Climatological Handbook (Meteorology Committee, Pacific Northwest River Basins Commission 1969).

Table 2—Analysis of variance for categories of frost damage

Source of variation	Degree of freedom	Severe Mean square	Severe F	Moderate to heavy Mean square	Moderate to heavy F	Light or none Mean square	Light or none F
Blocks (B)	2	351	2.7	50	0.8	1115	1.4
Phosphorus (P)	1	2172	17.0*	1873	29.6**	128	0.2
BxP ($Error_a$)	2	128		63		807	
Families (Fa)	17	1012	11.0***	598	5.2**	592	6.9***
PxFa	17	134	1.5	142	1.2	75	0.9
BxPxFa + BxFa($Error_b$)	68	92		116		86	

* = P <0.10; ** = P <0.05; *** = P <0.01.

Results and Discussion

The frost damage in spring 1985 occurred in a spring that, at first glance, appeared mild and warm. This damage was the first reported to red alder plantations since 1969 (DeBell and Wilson 1978). Similar damage also occurred in other newly established red alder plantations in Oregon and Washington, and local farmers reported one of the worst years on record for frost damage to berry crops. Temperature patterns in spring 1985 differed from those of the past 20 years in several ways (table 3). No frosts occurred from March 29 until April 19, a period normally having frequent and hard frosts. The mild weather was followed by several frosts, including one of -3.3 °C on April 26. The last frost of -2.2 °C occurred on May 12, the coldest since 1966. Thus, it appears that the extensive frost damage to newly planted alder and other crops in spring 1985 can be attributed primarily to unusually mild temperatures in late March and early April followed by repeated and sustained freezing temperatures from late April to mid-May.

Table 3—Comparison of temperature patterns near study site for spring 1985 and 20-year average1/

Time period	Number of frosts during time period		Temperature of coldest frost	
	1985	20-year average	1985	20-year average
			- - - - °C - - - -	
March:				
1-10	9	5.4	-3.8	-2.8
11-20	6	4.3	-3.0	-2.3
21-31	4	4.1	-1.5	-2.4
April:				
1-10	0	3.8	2/ N.F.	-1.4
11-20	2	3.9	-0.8	-1.3
21-30	5	2.7	-1.0	-1.2
May:				
1-10	1	1.1	0.0	-0.8
11-20	1	.5	-2.2	-0.8
21-31	0	.4	N.F.	-0.6

1/ Data obtained from records kept at official weather station, Olympia, Washington, airport.

2/ No frost occurred during time period.

About two-thirds of the containerized seedlings planted at the study site showed evidence of frost damage to the entire stem, and some had begun to resprout from the base. Although few container-grown seedlings were undamaged, field-collected wildlings (1 to 2 years old) planted in a few border rows were not visibly damaged.

Frost damage varied significantly among families and, to a lesser degree, by fertilizer treatment (table 2). Family differences were significant in all three damage categories (severe, moderate to heavy, and light or none). Of the trees in 9 families, 75 percent or more experienced severe damage (fig. 1). On the other hand, 6 families had a sizable portion of trees (15 percent or more) with little or no damage (fig. 2). If the two figures are compared, certain families lie at opposite ends in both categories. Thus, we might regard families 8, 9, and 15 as particularly sensitive to growing-season frosts because they had not only high percentages of stems severely damaged but also very low percentages of stems with little or no damage. Conversely, families 1, 5, 6, 14, and 16 might be regarded as somewhat tolerant of growing-season frosts because they had low percentages of stems severely damaged and the greatest percentages of stems that escaped with little or no damage.

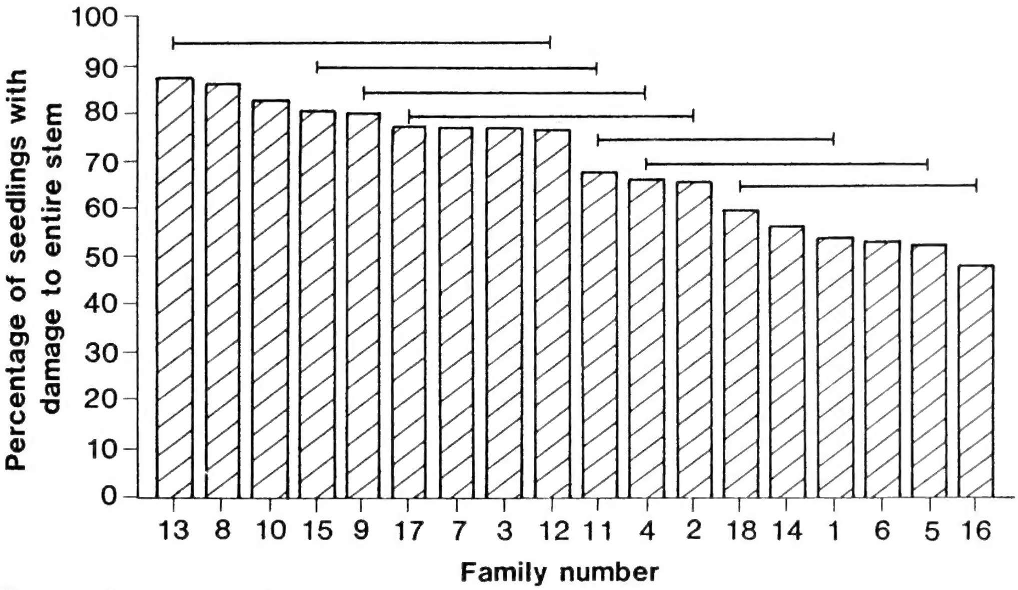

Figure 1.—Ranking of families according to percentage of seedlings with severe frost damage. Families joined by a common bar do not differ significantly at $P < 0.05$.

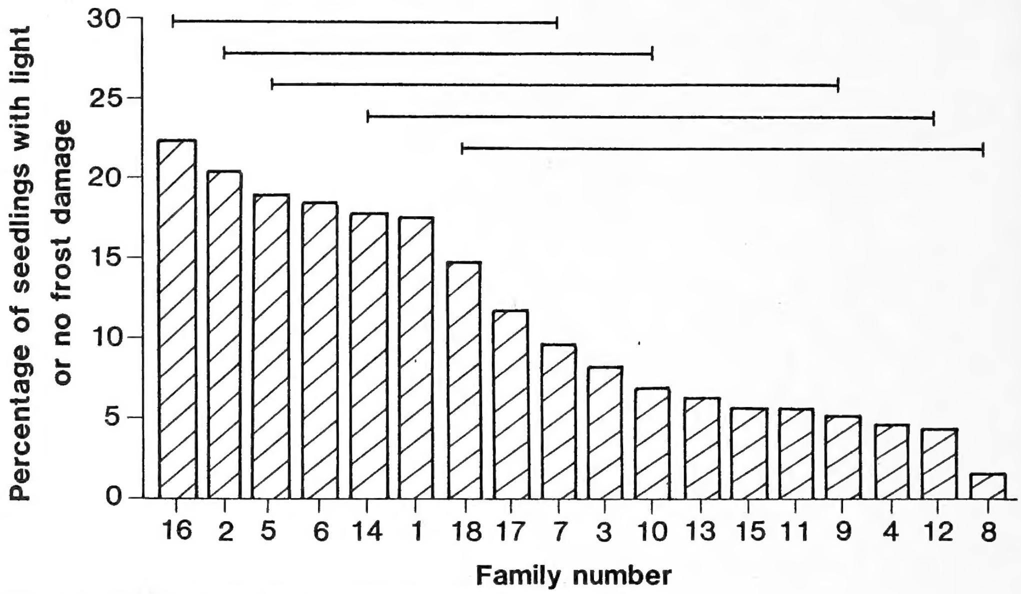

Figure 2.—Ranking of families according to percentage of seedlings with light or no frost damage. Families joined by a common bar do not differ significantly at $P < 0.05$.

Much of the variation in cold-hardiness or general frost tolerance of temperate zone species is related to geographic source (location and climatic characteristics of parent sites), primarily because of long-term natural selection associated with phenological differences (Wright 1976). Such relationships, however, were not apparent in our plantation. For example, families 15 and 16 originated from the same parent stand near Forks, Washington, and they varied greatly in frost damage. In contrast, families 5 and 6 suffered less damage than most other families and came from the same parent site, and families 8 and 9 were heavily damaged and came from another parent site. No climatic differences between these two sites that might explain such differences in frost damage are apparent, however.

The lack of an apparent relation between frost damage of various families and characteristics of parent sites may result simply from insensitivity of the design. Our study was not designed to test differences in population or parent sites; rather, we selected families for outplanting based on seed availability and presumed capacity for good growth at the study site. All families originated from a rather limited area—low elevation sites in western Washington and southern British Columbia. Moreover, methods of propagation may have such an important effect on frost damage or may interact to such degree with family differences that variation associated with parent sites is masked.

On the other hand, damage to unseasonable events (trees had been leaved out for at least 1 month) may not be as strongly related to characteristics of parent sites as is cold-hardiness in general. The fact that families from the same site appear in both sensitive and tolerant groups parallels earlier indications that some phenotypic and genetic traits of red alder may vary as much within a single stand as they do from site to site, at least within a limited area or breeding zone (DeBell and Wilson 1978; DeBell and others 1984; Hook and others, in press). Moreover, work in Scotland shows that red alder provenances from Washington, British Columbia, and Alaska dehardened rapidly in late March, and average date of bud burst of the southerly provenances was only 3 days later than that of Alaskan provenances (Cannell and others, in press).

Effects of phosphorus fertilizer varied with the degree (or category) of frost damage. Seedlings in fertilized plots suffered significantly more heavy frost damage (74 percent of seedlings with entire stem damaged or necrotic) than those in unfertilized plots (65 percent of seedlings). In contrast, the percentage of seedlings with moderate damage was significantly lower in fertilized plots (15 percent) than in unfertilized plots (21 percent); moreover, the percentage of seedlings with little or no damage did not differ significantly with fertilizer treatment.

The increased heavy frost damage to seedlings planted in fertilized plots is puzzling. No apparent differences were found between fertilizer treatments in the development of other vegetation. Excavation of a few seedlings revealed little egress from the root plugs to the surrounding soil. Presumably, differences between fertilizer treatments in P uptake and assimilation by the alder seedlings would still be rather minor at the time of the frosts. The small differences in frost damage are too consistent (fig. 3), however, to be dismissed. Perhaps minor differences in P status caused minute changes in rate of phenological development, which led to corresponding differences in suceptibility to frost damage.

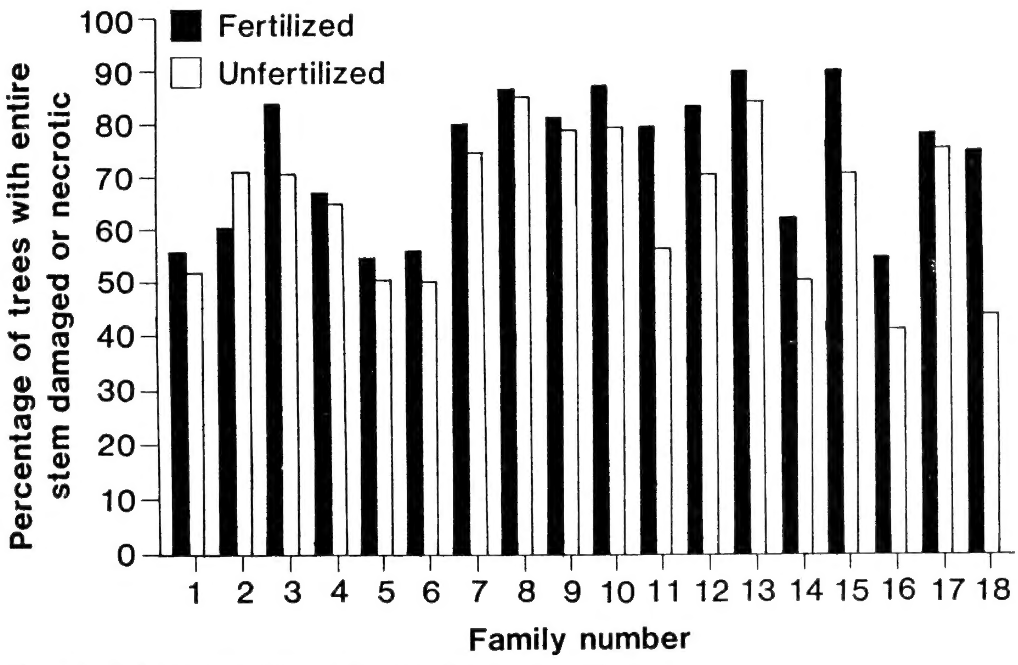

Figure 3.—Influence of fertilizer on heavy frost damage sustained by red alder families.

Differences in phenological development may also help explain the lack of damage in the wildlings planted in the border rows. Root systems of these trees were undoubtedly "shocked" by the transplanting operation, and phenological development (flushing) appeared to be somewhat delayed.

Although such problems have been negligible in recent (after 1970) alder plantings in Oregon and Washington, unseasonable frosts during the 1st year after planting caused considerable damage in two plantings of red alder in earlier years. Tarrant (1961) reported severe frost damage during the fall and spring after planting when alder stock from seed collected near Olympia, Washington (15 m above sea level), was planted in

1933 at 700 m elevation in the Wind River Experimental Forest near Carson, Washington. Moreover, one installation (Olympia, Washington) of a provenance trial established in 1969 was damaged so severely by early fall freezes in the 1st and 2d year after planting that further measurements at the site were abandoned (DeBell and Wilson 1978). Two of the provenances (Juneau, Alaska, and Sandpoint, Idaho) suffered much less damage than other sources from Oregon, Washington, and southern British Columbia, but they also grew much more slowly.

Older red alder stands may also be severely damaged and killed by unseasonable frosts (Duffield 1956), but such occurrences are uncommon. In general, older natural stands and plantations appear to be less susceptible and better able to recover than newly planted seedlings. None of our established alder plantations, aged 3 to 10 years, suffered any observable damage in spring 1985.

To minimize risks of damage from late spring frosts in the 1986 replanting of our study, we held seedlings in a cold room (2 °C) from late February until they were planted in early May. Survival at the end of the first growing season exceeded 98 percent.

Acknowledgments

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English Equivalents

1 kilogram (kg) = 2.2 pounds
1 meter (m) = 3.28 feet
1 kilometer (km) = 0.62 mile
1 hectare (ha) = 2.47 acres
Degrees Celsius (°C) = 5/9 (°F-32)

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